ORC*HI*DSS: OPTICAL, RADIO CONTINUUM AND HI DEEP SPECTROSCOPIC SURVEY

4MOST FOLLOW-UP OF THE MEERKAT DEEP EXTRAGALACTIC SURVEYS

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ORCHIDSS - TEAM

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ORCHIDSS - ELEVATOR PITCH

ORCHIDSS will provide a highly complete spectroscopic survey of the radio continuum selected population out to z=1.4 that will:

I - Enable unique studies of the HI evolution of galaxies in parameter space that would be otherwise inaccessible until the SKA era

II - Provide a census of the star-formation and accretion history of galaxies in this period unbiased by dust obscuration

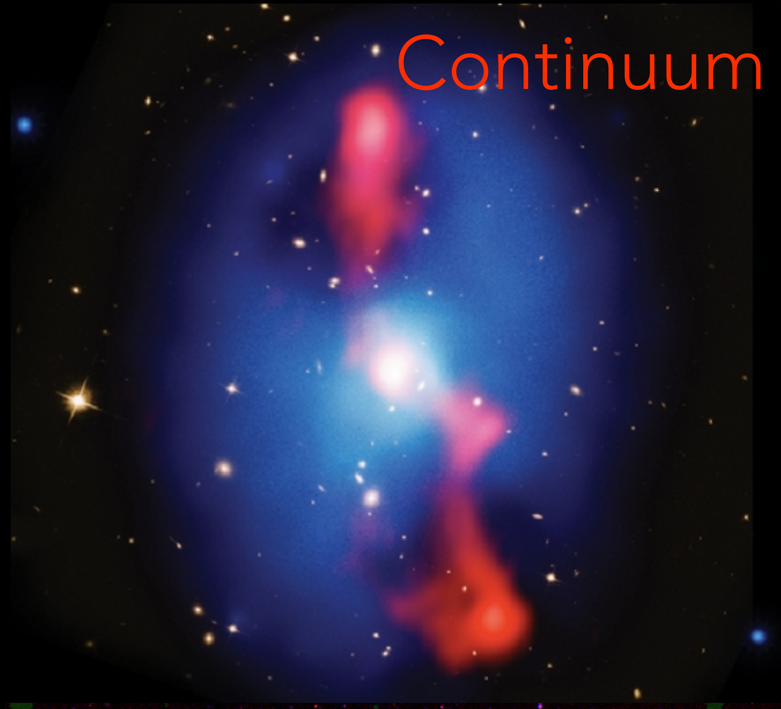
III - Provide an enormous legacy dataset for future galaxy evolution studies and the prime redshift resource for the next generation of deep radio surveys with the Square Kilometre Array

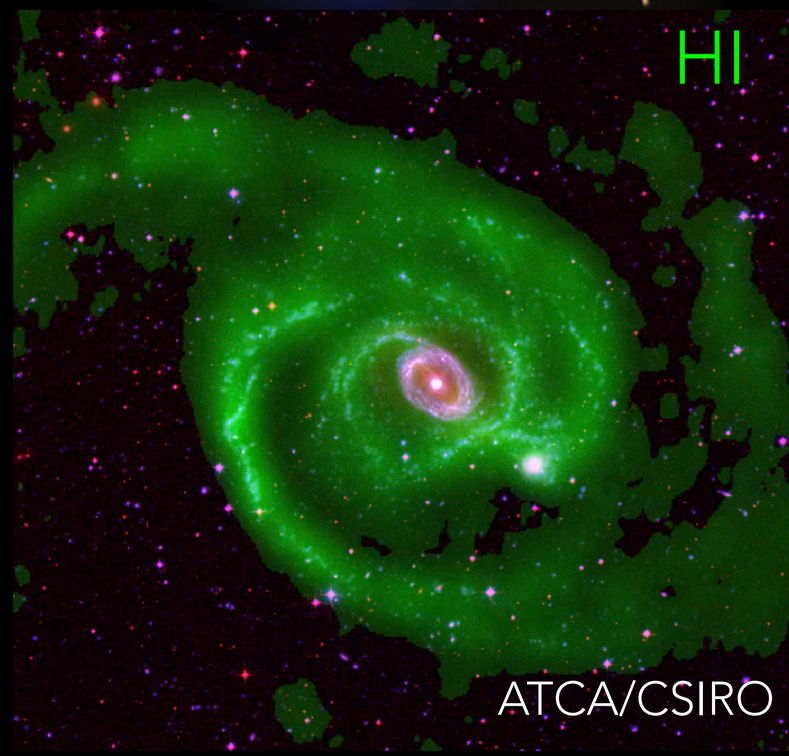
POWER OF RADIO OBSERVATIONS

- **Radio continuum**
  Synchrotron emission - *AGN activity and <u>obscuration</u> <u>free</u> measure of star-formation*

- **Spectral lines**
  Atomic gas (HI) - *gas mass/fraction, kinematics*
  Masers (OH) - *extreme SF; mergers*

- **Polarisation**
  Rotation measure grids - *magnetic fields in the cosmic web/LSS*
  Polarisation - *Magnetic fields in galaxies/AGN*





MEERKAT

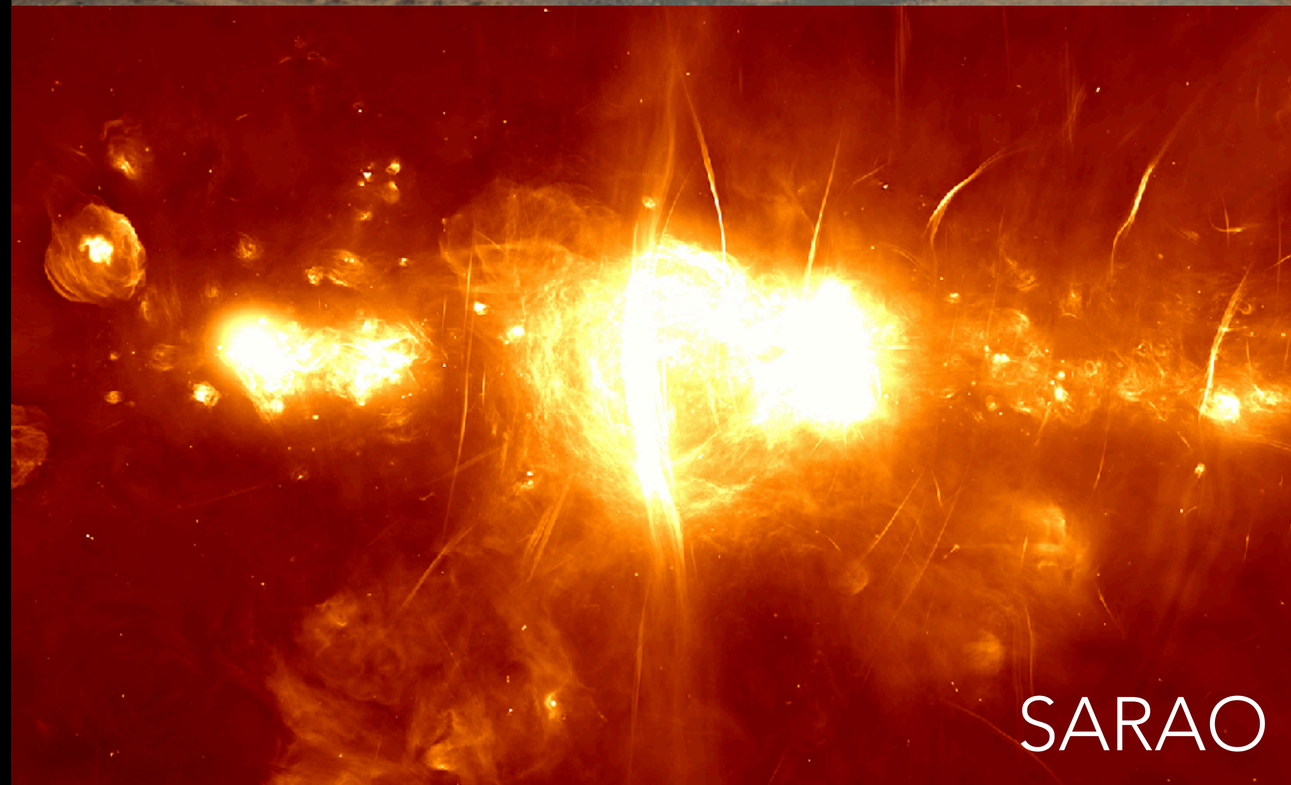
- SKA Precursor

- 64 antennas - up to 8km baselines

  L-band (0.9 - 1.7 GHz)
  (21cm HI emission at $z < 0.57$)

  UHF (0.58 - 1 GHz)
  (21cm HI emission at $0.4 < z < 1.4$)

  Full polarisation and high spectral resolution



THE MEERKAT DEEP EXTRAGALACTIC SURVEYS

MIGHTEE: The MeerKAT International Giga-Hertz Tiered Extragalactic Exploration survey

PIs: Jarvis, Taylor

L-band (900-1700 MHz):

- 20 sq.deg. over 4 DDF
- ~1uJy rms (Factor of ~4 deeper than JVLA-COSMOS)
- $M_{HI} \sim 10^{10.5}$ *at z~0.3*

COSMOS Verification data:
~2.2uJy/beam RMS

CREDIT: IAN HEYWOOD

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MeerKAT Fornax Survey:
*PI: Serra (*NB: Agreement with MIGHTEE on use of sky behind the cluster)

L-band (900-1700 MHz):

- ~~20~~ **32** sq.deg.
- ~1uJy rms (Factor of ~4 deeper than JVLA-COSMOS)
- $M_{HI} \sim 10^{10.5}$ *at z~0.3*

COSMOS Verification data:
~2.2uJy/beam RMS

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LADUMA: Looking at the Distant Universe with the MeerKAT Array
PIs: Baker, Blyth, Holwerda

L-band (900-1700 MHz):

- 4 sq.deg
- *Twice as deep as MIGHTEE for HI*

UHF Band (580-1015 MHz):

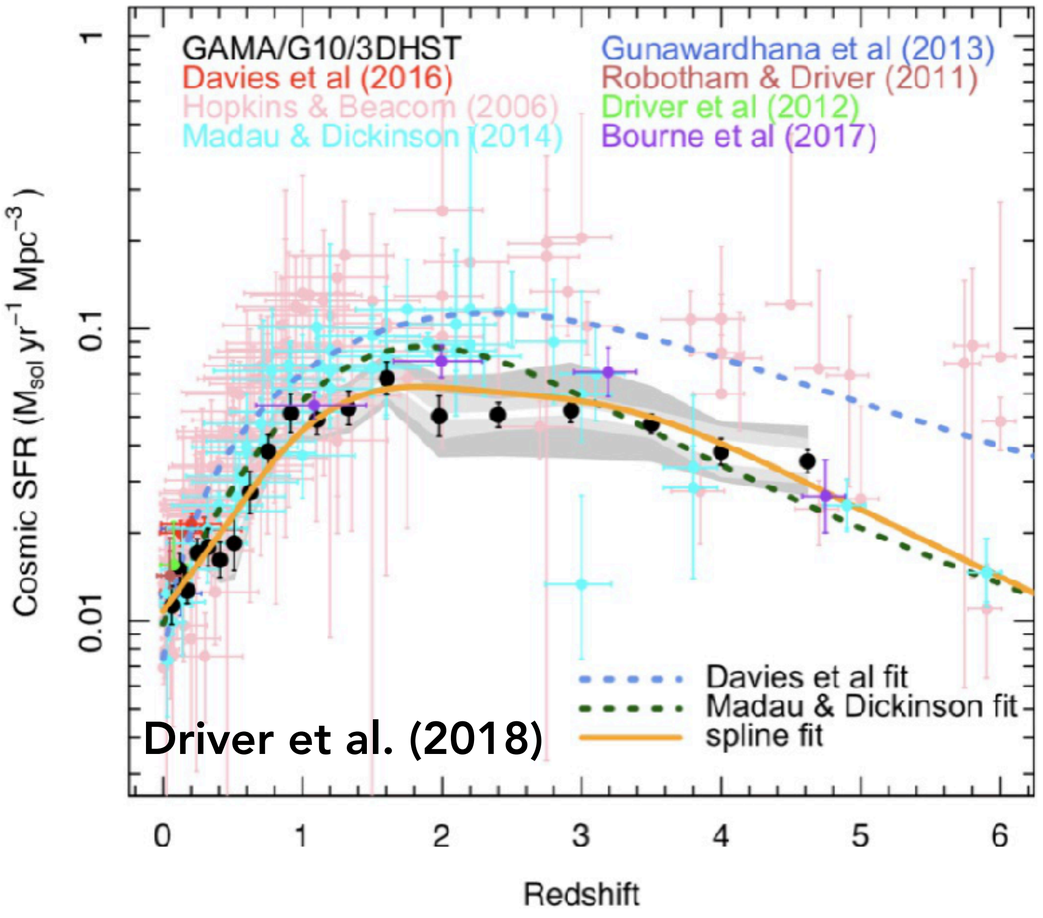
- >4sq.deg
- $M_{HI} \sim 10^{10.5}$ *at z~0.9*

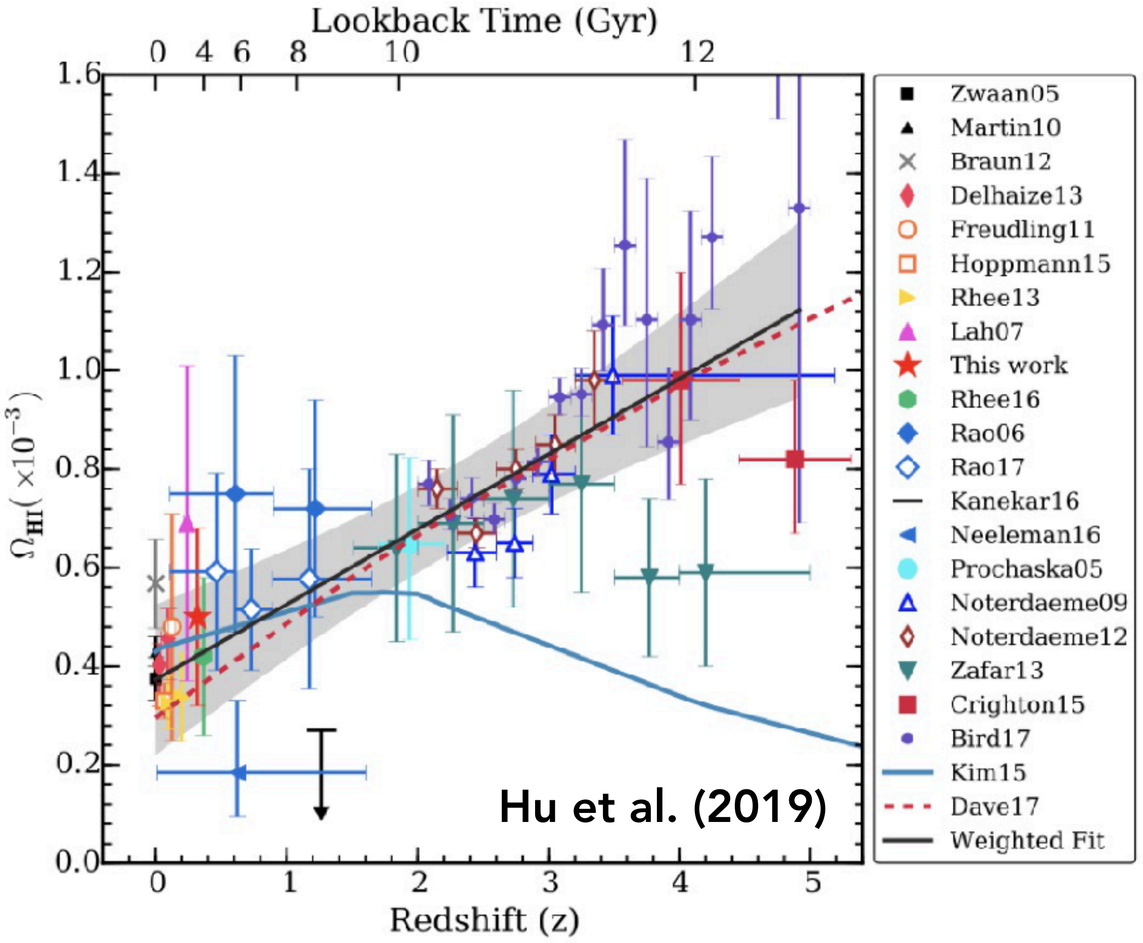
HI Detections
Credit:
M Glowacki

SCIENTIFIC GOALS OF ORCHIDSS

- What is the cosmic history of neutral hydrogen?
- What is the life cycle of gas in galaxies?
- What is the accretion history of AGN?
  (In all modes of accretion)
- How does feedback associated with that accretion impact the gas reservoir of galaxies?

THE COSMIC HISTORY OF NEUTRAL HYDROGEN





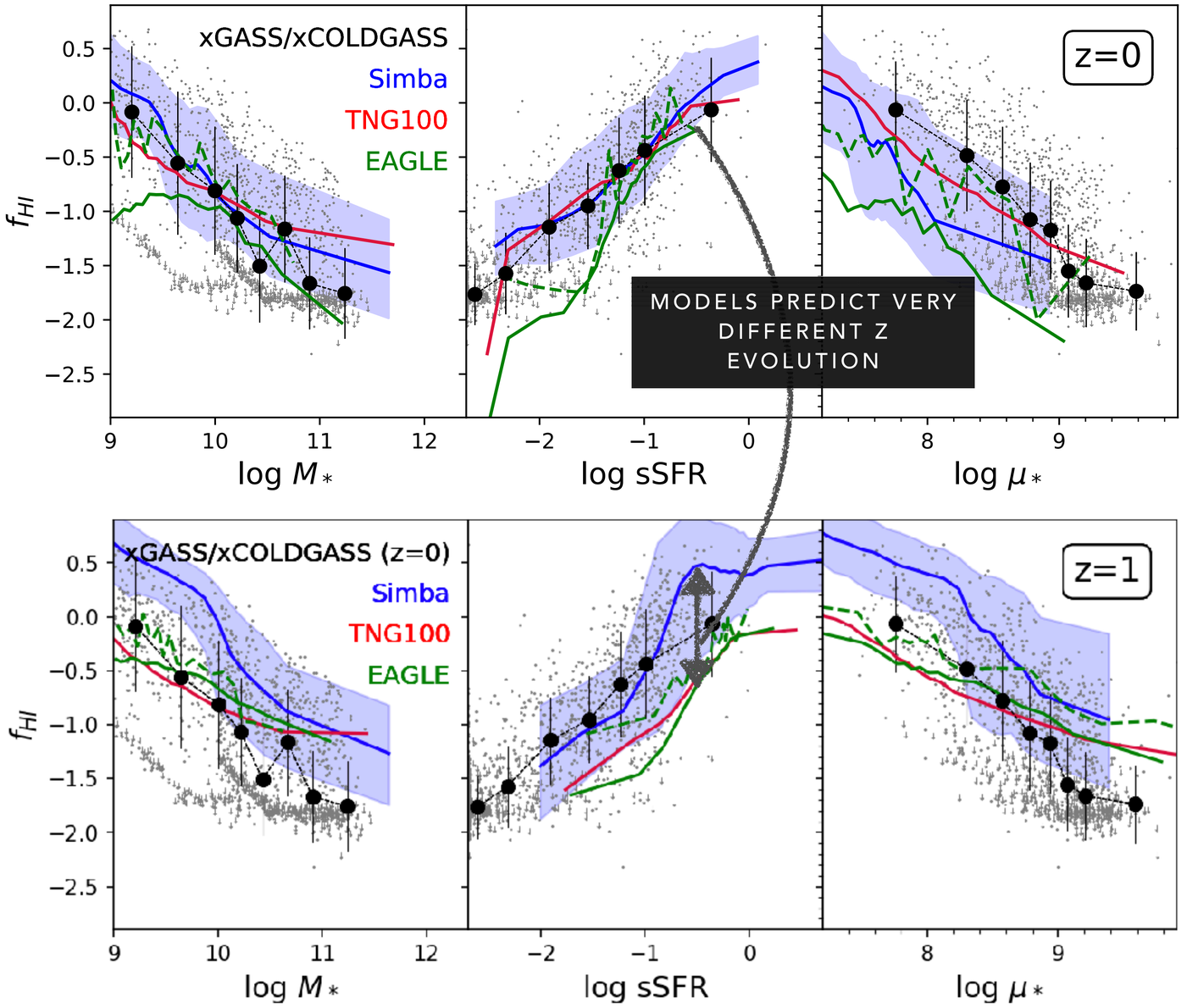
While the cosmic SF history is well constrained - our constraints on the reservoir of fuel available for SF is much more poorly understood

THE LIFE CYCLE OF GAS IN GALAXIES

What are the fundamental scaling relations between HI and …

- Star-formation
- Mass (stellar and halo)
- Metallicity

as a function of redshift and environment?



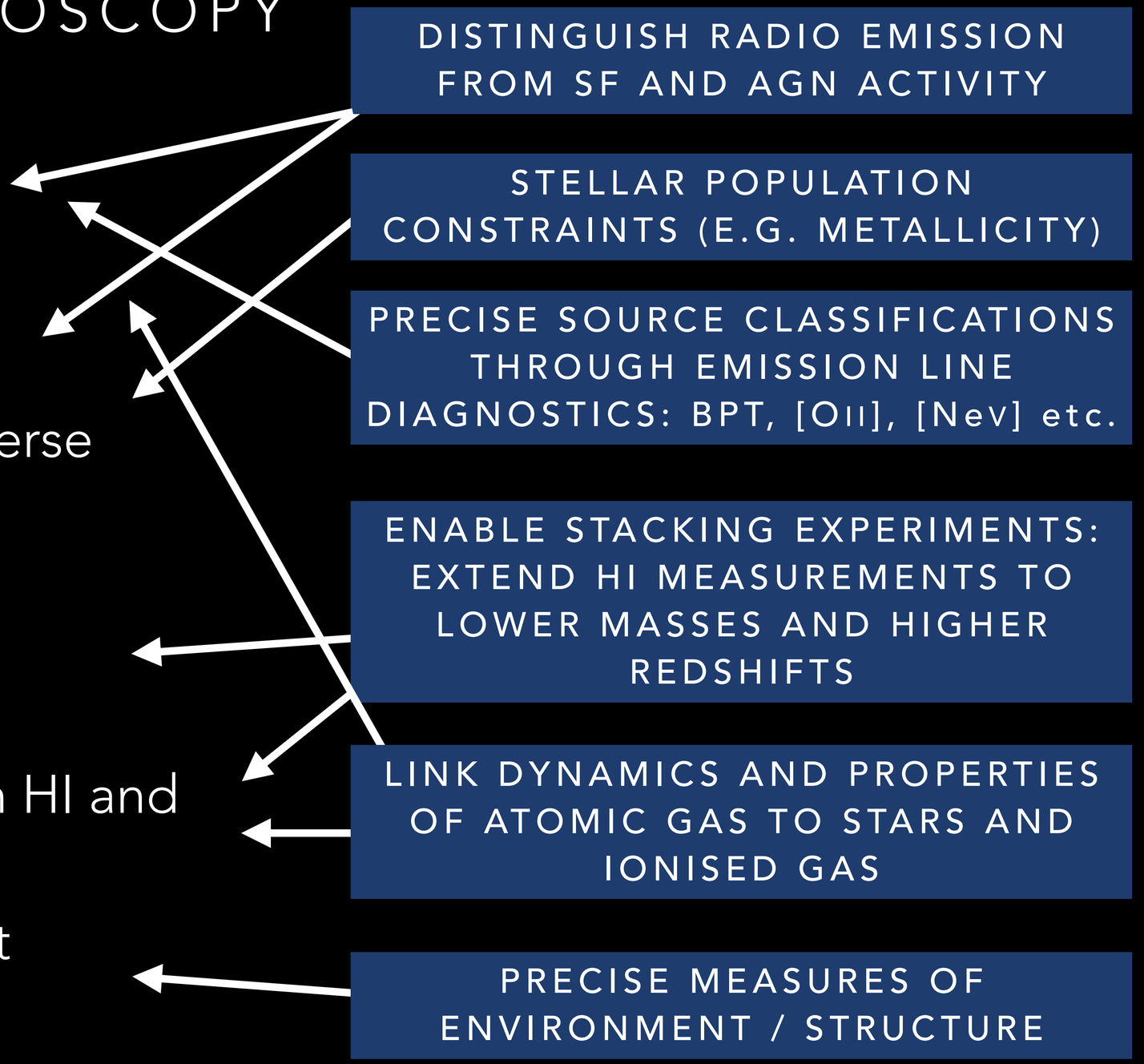
Adapted from Davé et al. (2020)

SECONDARY SCIENCE GOALS ENABLED BY ORCHIDSS AND MEERKAT

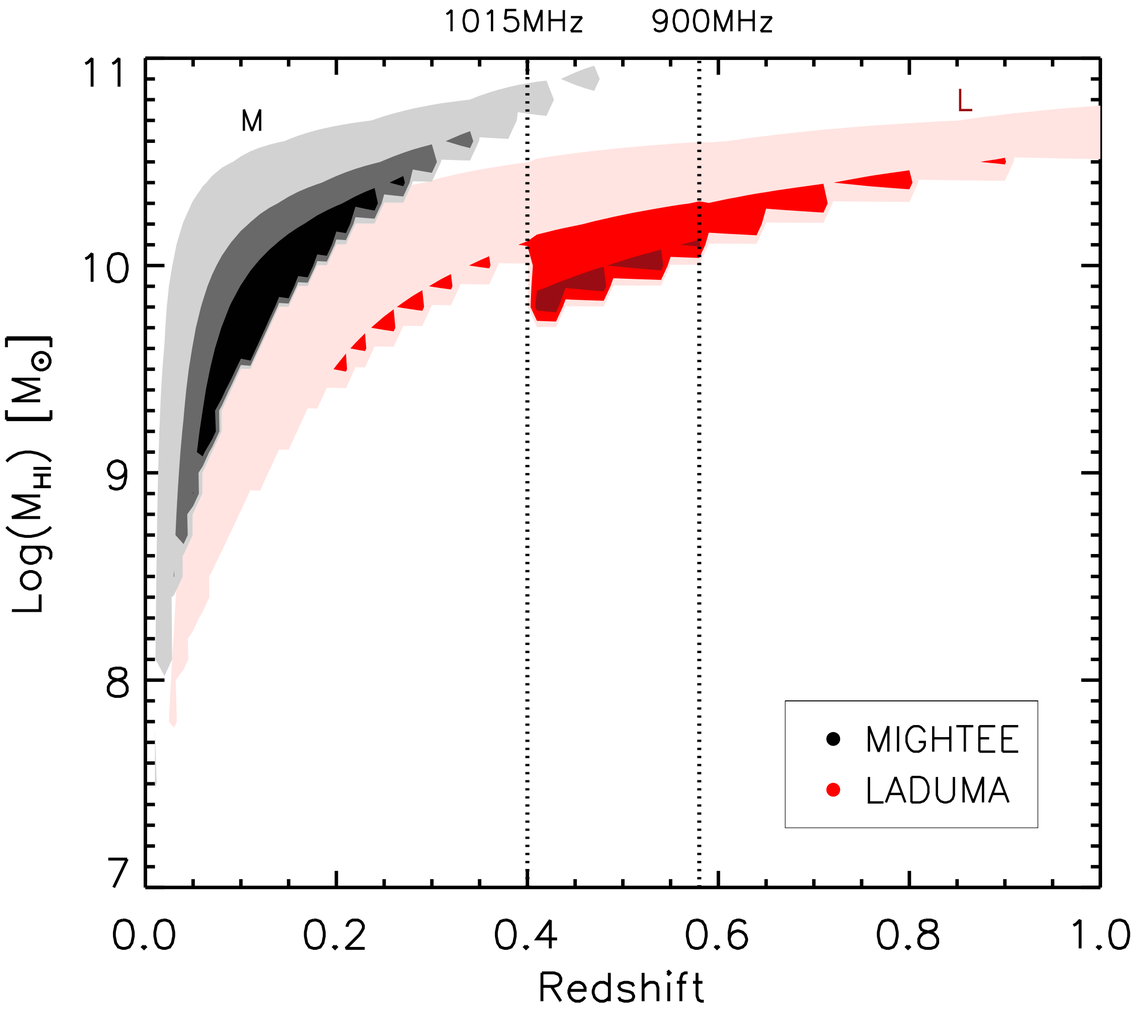
- A complete census of AGN and SF activity in the LSST Deep Drilling Fields at $z < 1.4$
- Studies of the Baryonic Tully-Fisher relation out to $z \sim 1.4$
- An alternative window into the galaxy merger history through OH megamasers
- … and many more beyond…

THE NEED FOR SPECTROSCOPY

- Accretion history and feedback
- Star-formation history of the Universe
- **HI:**
  - Cosmic HI history
  - Fundamental relations between HI and star-formation/mass/… vs z
  - HI as a function of environment

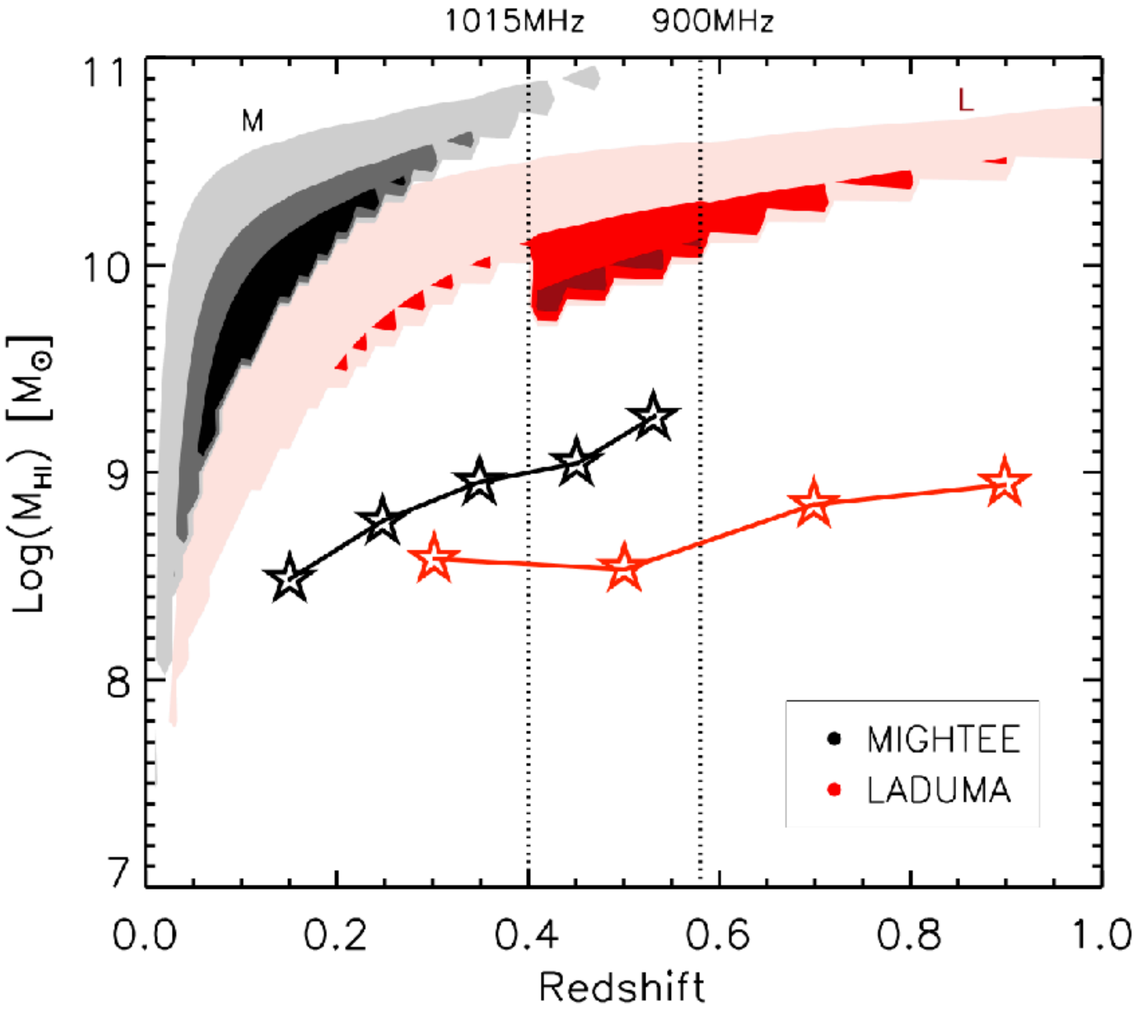


Maddox et al. (2016)



MeerKAT surveys represent state-of-the-art, but blind detections limited to only the most HI massive sources at higher redshifts

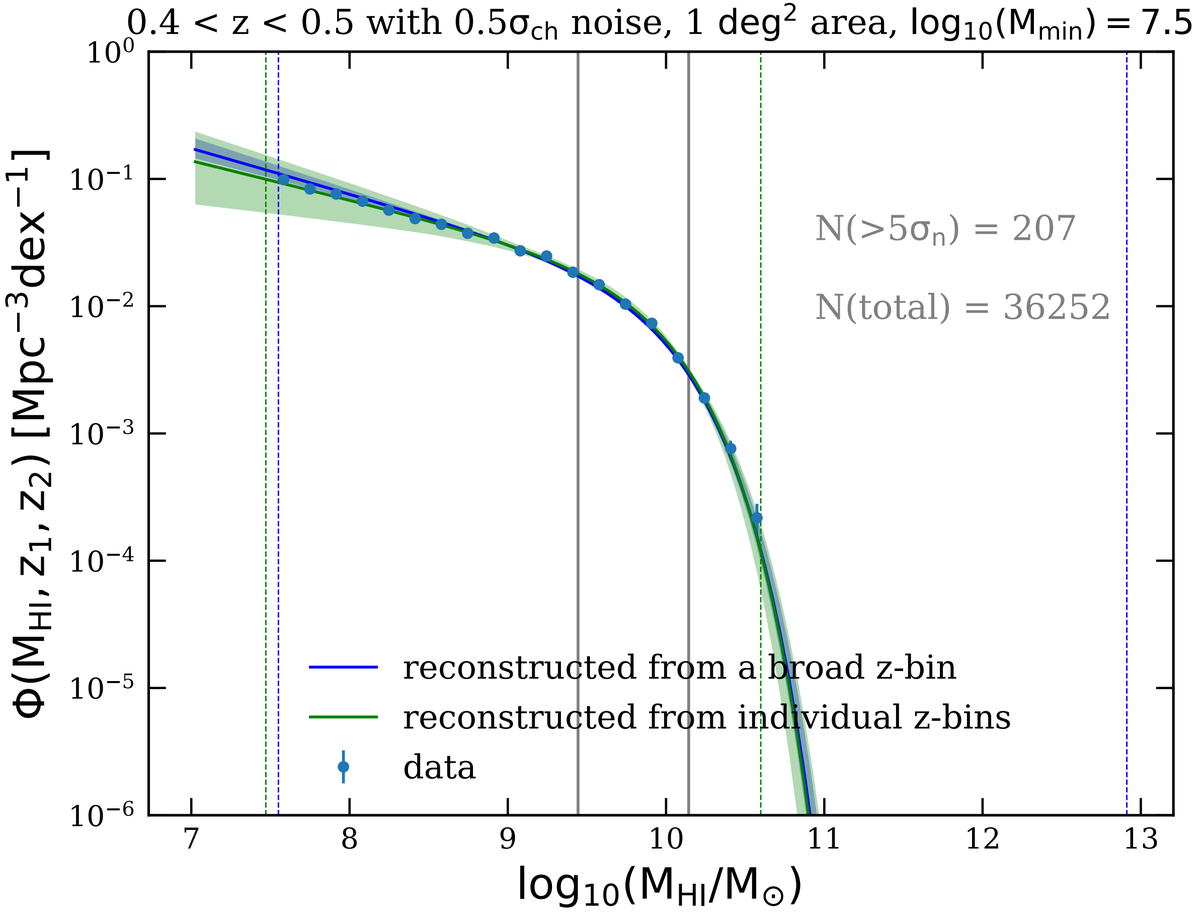
Maddox et al. (2016)



Large spectroscopic samples of optical spectra unlock huge new parameter space - *allowing us to probe HI as a function of mass/SFR/ environment etc.*

Sensitivity reached with ORCHIDSS - with 10 bins per redshift slice (e.g. mass/SFR/environment)

Pan et al. (2019)



Parametric stacking techniques can constrain the distribution of HI properties far below the detection limit

PROPOSED SURVEY

ORCHIDSS Deep: All radio continuum (RC) detected sources at $z_{phot} < 1.4$ in LSST DDF (/WAVES-Deep fieldd)

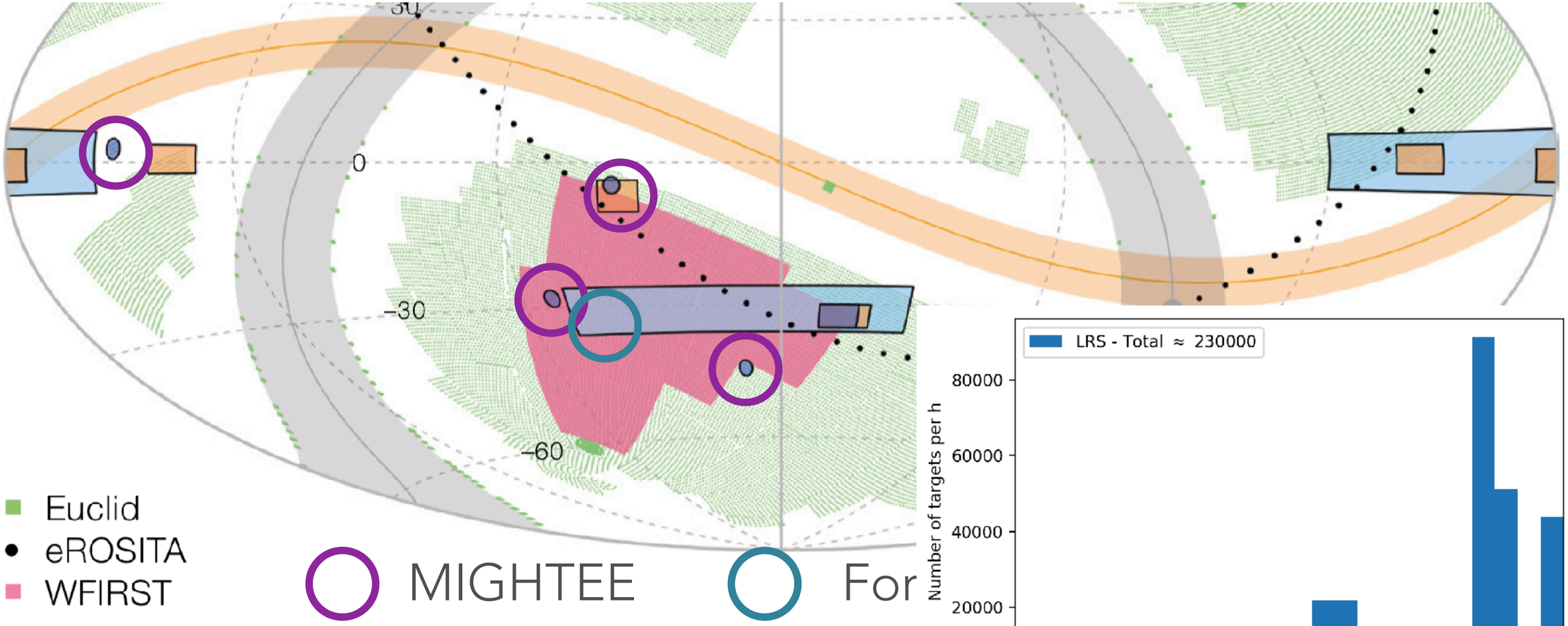
~170k Targets over 16 sq.deg

ORCHIDSS Wide: All RC detected sources at $z_{phot} < 0.57$ over the remaining area of the full MIGHTEE footprint

~60k targets of 19 sq.deg

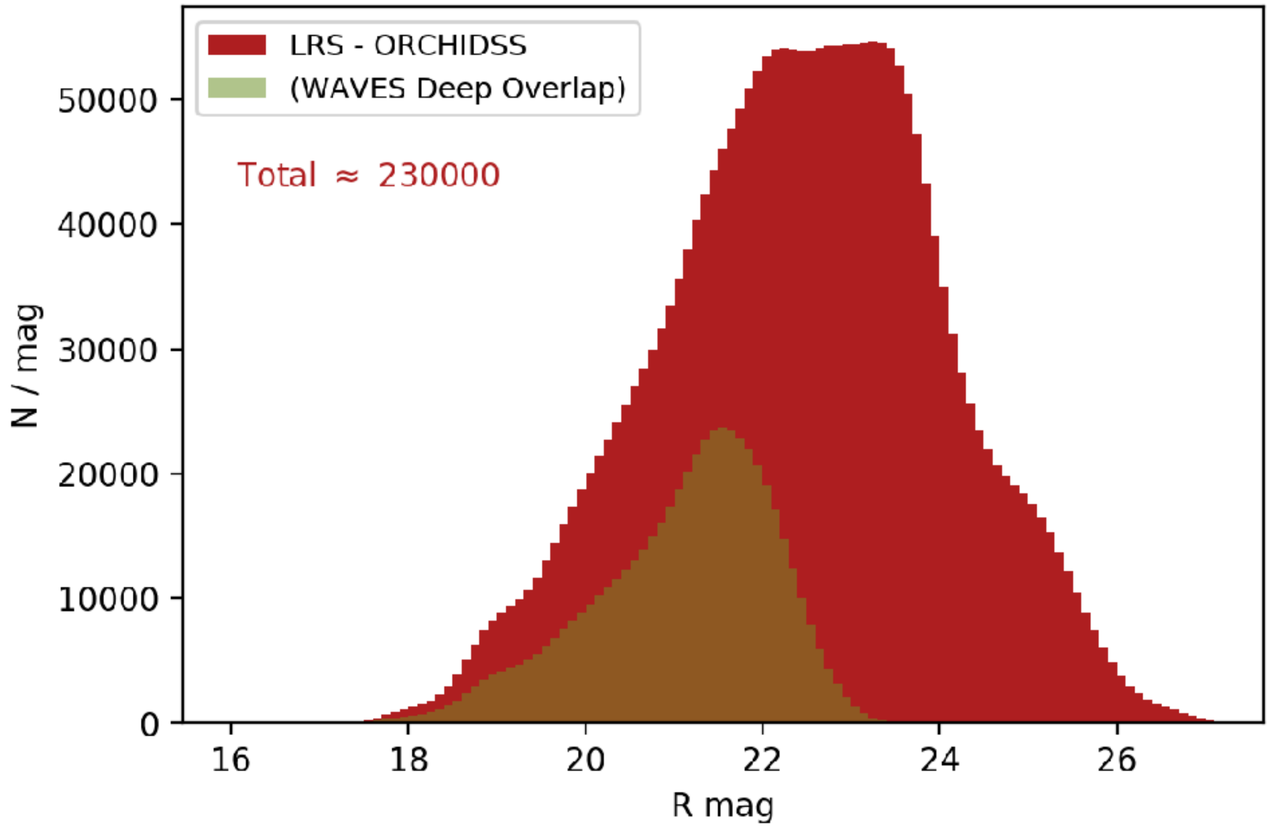
= ***~230,000 targets x <1hr> LRS (Participating survey)***

PROPOSED SURVEY



Driver et al. (2019; WAVES Messenger article)

PROPOSED SURVEY

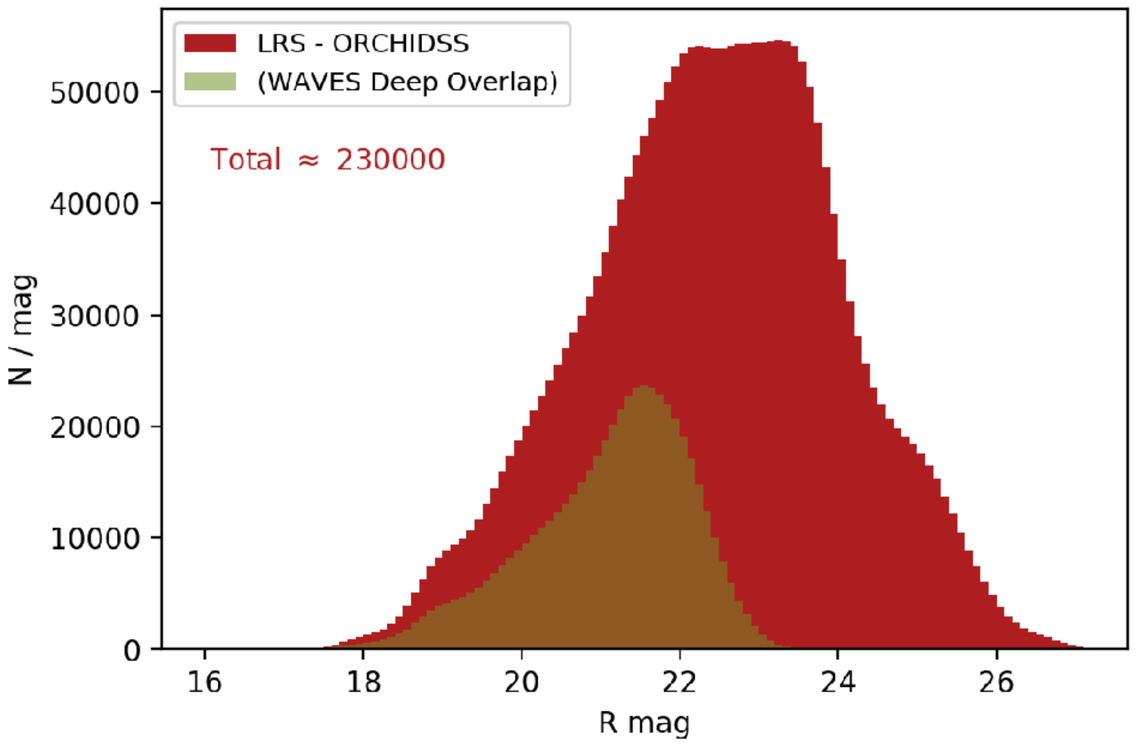


Spectral success criteria = redshift measurement

ORCHIDSS sample selected on activity - expect strong emission lines

Exposure times ranging from 20min to a maximum of 3 hours - 1 hour average

PROPOSED SURVEY



Survey regions	RA (deg)	Dec (deg)	Area (deg²)	Range of targets density (targets/deg²)	Range and average t_{exp} (hours)	Magnitude range[1]
CDFS	52.5	-28.6	4.2	10435	0.3 - 3 1	22.0 - 25.3
CDFS Wide[2]	52.5	-28.6	4.1	2950	0.3 - 2 1	19.0-23.6
COSMOS	150.1	2.2	4.2	10435	0.3 - 3 1	22.0 - 25.3
XMM-LSS	35.5	-4.8	4.2	10435	0.3 - 3 1	22.0 - 25.3
XMM-LSS Wide[2]	35.5	-4.8	2.5	2950	0.3 - 2 1	19.0-23.6
ES1	9.45	-44.5	4.2	10435	0.3 - 3 1	22.0 - 25.3
Fornax Wide	52.5	-35.5	12	2950	0.3 - 2 1	19.0-23.6

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Quantities needed from 4MOST spectra:

- **Redshifts**
- Emission line properties
- Dynamical measurements of gas and stellar components
- Source classifications - star-forming vs AGN (and accretion modes)
- Physical properties - stellar masses, star-formation rates, etc.

ORCHIDSS Team has extensive experience in many of these aspects

Expect to contribute FTE, expertise and computing resources to IWGs 8 and 9

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(~250k LRS fhr)

Extra Slides

THE LIFE CYCLE OF GAS IN GALAXIES

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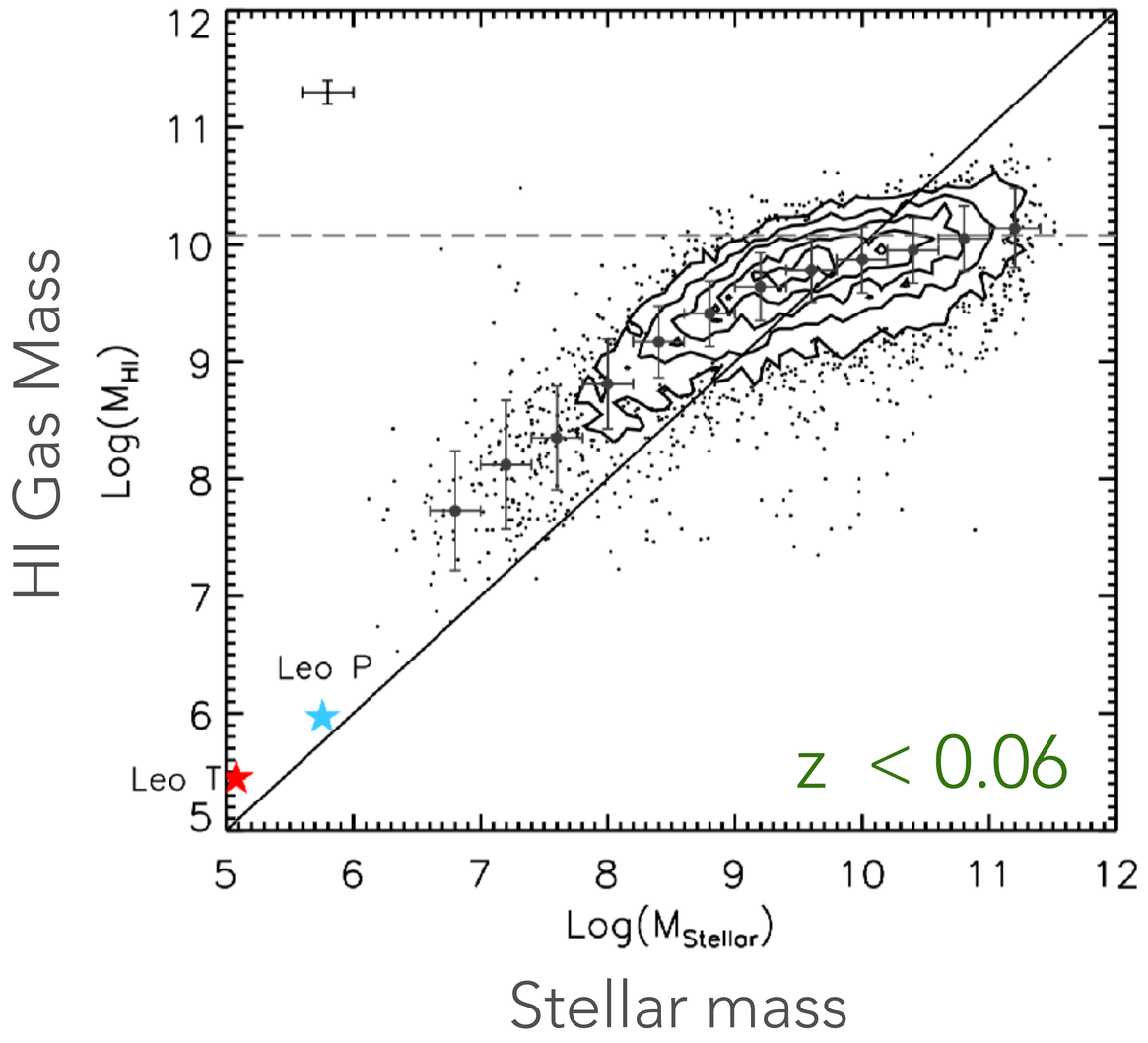
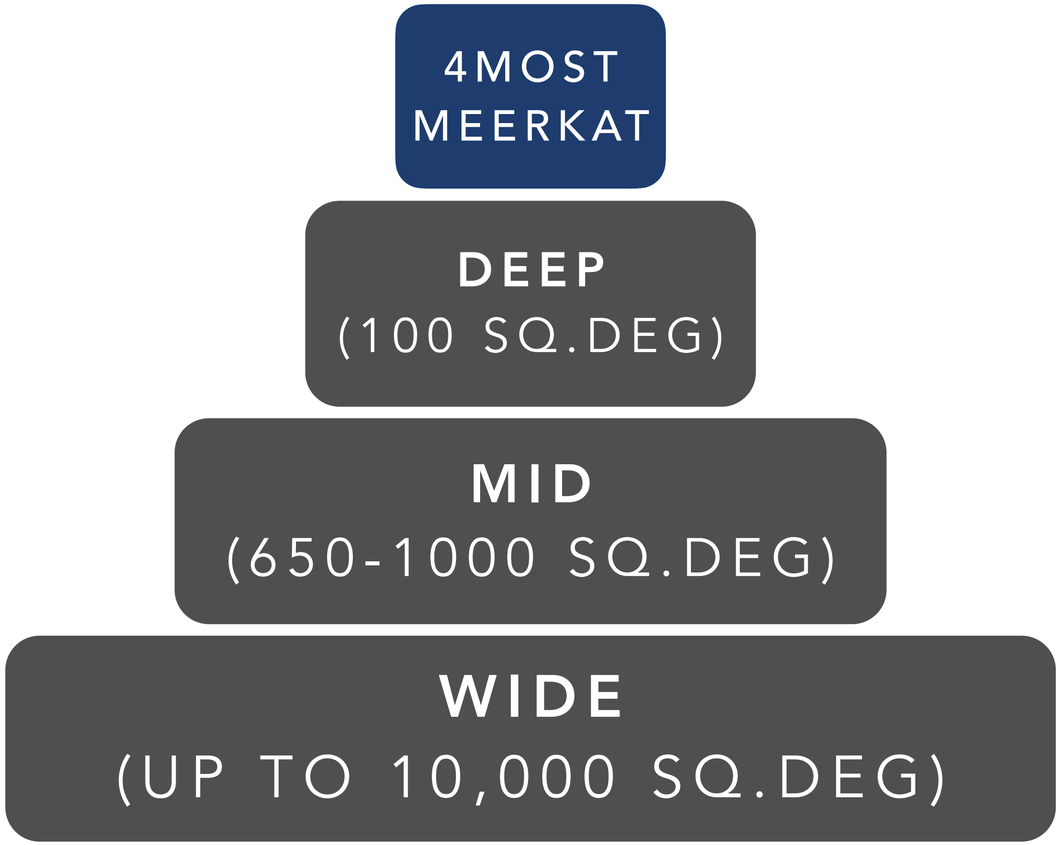
as a function of redshift and environment?

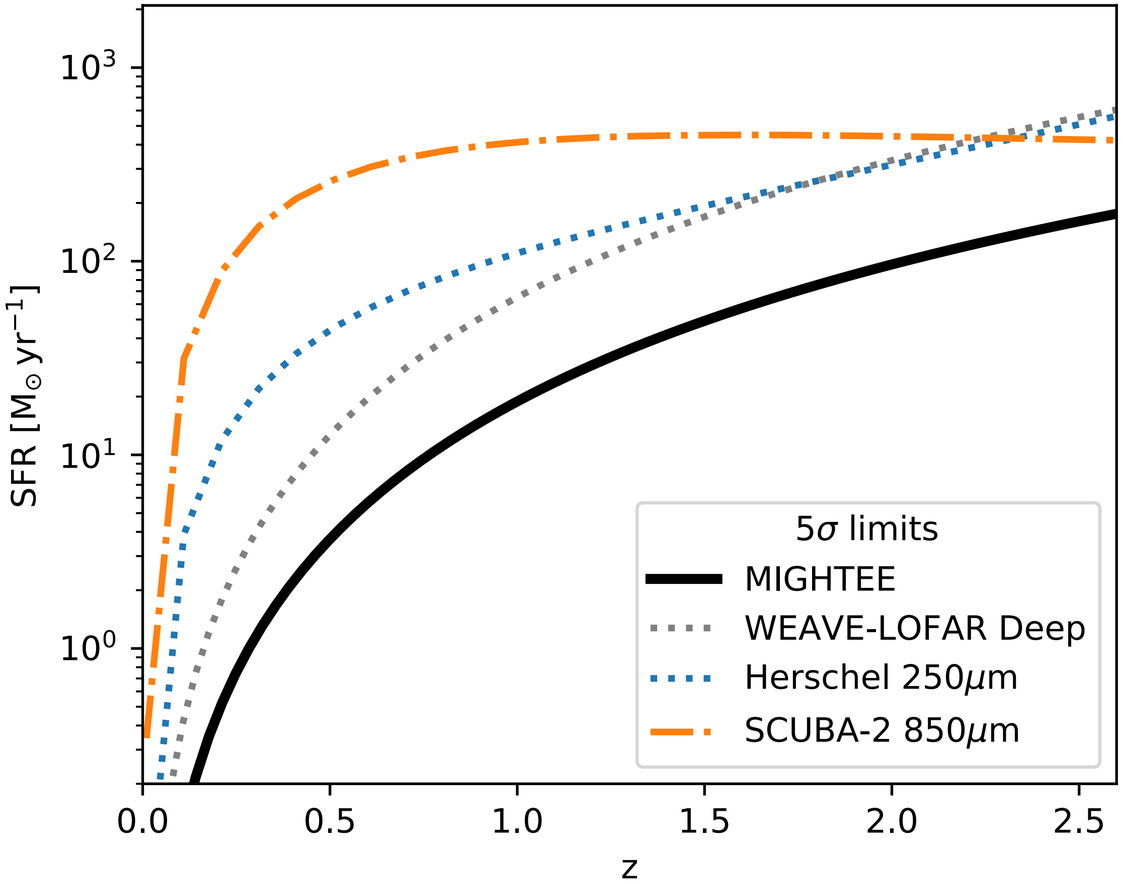
Maddox et al. (2015)



COMPLEMENTARITY WITH WEAVE-LOFAR

SMITH ET AL. (2016) - ARXIV: 1611.02706





WEAVE-LOFAR Deep Fields ideally suited to study of luminous/rare objects across time

Spectroscopy of MIGHTEE fields open up regime of sub-M* galaxies out to z~1.5

HI science is unique to MIGHTEE/LADUMA fields